*RADIATION CALCULATOR**

Example Problems Showing Use of the General Electric Radiation Calculator

To save time in the handling of calculations of radiant energy the General Electric Radiation Calculator GEN - 15B presents energy data in various units as derived from a source temperature that can be set on the rule in any one of four temperature scales. The basic functions and formula upon which the Calculator is based are presented on the faces of the Calculator. To best illustrate use of the Radiation Calculator several sample problems are given below followed by a partial bibliography of sources of additional information on radiation calculations.

Example I

The graphite plate of a particular metal-shell vacuum tube operates at 500° C. At an emissivity of only about 0.08 (Handbook of Chemistry and Physics), it is only eight per cent as good an energy radiator as a blackbody. If 500° C is set at the index, it is found that a blackbody radiates 2 watts per square centimeter while carbon, at its low value of emissivity, radiates 1.6×10^{-1} watts per square centimeter as read opposite the appropriate emissivity. This radiant energy is absorbed in the metal envelope of the tube. Assuming a temperature of 100° C at the metal, we may compute the energy radiated to the carbon by the metal. In this case, since the metal is the surrounding, the emissivity factor of the metal does not enter into the calculation. With 100° C set at the index the energy reading at the index is 1.1×10^{-1} watts per square centimeter. By subtraction it is found that 5.0×10^{-2} watts per square centimeter is the net radiation retained at the metal envelope from plate dissipation.

If a glass envelope is used, the problem becomes more complex, since a portion of the radiation is

*The rule, designated GEN-15B, is printed on vinyl plastic and is satisfactory for order-of-magnitude calculations. It may be obtained, postpaid, at $1.50 from the General Electric Company, 1 River Road, Schenectady, N.Y.

Example I (Cont'd)

transmitted by the glass. It is then desirable to find how much of the radiated energy is transmitted. At 2.5 microns, this glass begins to be a poor transmitter of infrared radiation. On the percentage-increment scale, 2.5 microns for this particular temperature (500° C) falls at 6 per cent. Thus approximately 6 per cent of the energy is transmitted by the glass, while 94 per cent of the energy radiated by the plate is absorbed by the glass. Since the percentage-increment scale is for blackbody distribution, the percentage of energy transmitted is only an approximation.

Example II

In another device it is desirable to use a lead-sulfide photoconductive detector to measure the radiant energy from a blackbody radiator varying between 1000 and 2000° F. To determine the order of accuracy to be expected in such an application, the spectral characteristics of the lead-sulfide cell are important. By an approximation of the published spectral response we assume that the cell does not respond to wavelengths longer than 3.3 microns. Then for 1000° F. the percentage-increment scale will show that only about 20 percent of the energy from the source is available to the lead-sulfide cell to be converted into a usable signal. At 1500° F, reading the percentage-increment scale again, 40 per cent of the energy is available for signal at the lead-sulfide cell. At 2000° F, 3.3 microns falls opposite about 56 percent; thus, 56 percent of the energy of the blackbody at this temperature is available for signal at the lead-sulfide cell. Thus an expected 2:1 variation in signal will occur due to spectral responsivity exclusive of energy variations due to temperature alone.

Example III

For a filter problem it may be desirable to obtain the source energy that falls in a wavelength increment. Suppose for a blackbody source at 1000° K the energy falling between 1.0 and 1.2 microns is desired. The maximum, of course, falls at 2.89 microns as seen on the wavelength scale. The total radiated energy is 5.7 watts per square centimeter. At 1.0 micron, 0.03 percent of the total energy falls below 1 micron and at 1.2 microns, 0.22 percent falls below 1.2 microns. Thus computing the percents of the energy below these wave-

lengths and subtracting one finds 0.011 watts per square centimeter between 1.0 and 1.2 microns wavelength.

Using the $W_\lambda / W_{\lambda\,max}$ (ratio of energy at wavelength to energy at maximum wavelength) scale for this same problem it is found that 0.042 of the energy at the maximum falls at 1.1 microns. The maximum value is 1.28 watts per square centimeter per micron wavelength increment; thus for the 0.2 micron filter width, 0.011 watts per square centimeter pass the filter subject, of course, to the filter transmission within that band width.

Example IV

Another problem might be the desirability of plotting blackbody curves at some temperature. For a temperature of 1000° K, set this temperature on the index. $W_\lambda / W_{\lambda\,max}$ values are found above the wavelength scale from which the curve of spectral emittance vs. wavelength can be plotted.

Example V

Instead of determining the energy emitted by a source operating at some temperature it is possible to get the number of photons per second per unit source area. For a source at 1000° K set the index again at this temperature and read 1.55×10^{20} photons per second per square centimeter on the proper scale.

The next scale below, gives photon energy in electron volts for a particular setting of source temperature which corresponds to the wavelength maximum or any wavelength within the range of the calculator. The wavelength is set on the index and the photon energy is read on that scale.

At the temperature of 1000° K the wavelength maximum is 2.89 microns and the photon energy is 0.43 electron volts. For a wavelength of 0.55 microns (green light) the photon energy is 2.25 electron volts.

Also when working with photoemissive surfaces the work function of the material might be expressed in electron volts, e.g. for some photocathode the work function is 2.0 electron volts. Using the calculator this corresponds to radiation of 0.62 microns (6200Å) wavelength.

Likewise a simple conversion is available to waves per centimeter or wave numbers corresponding to some wavelength.

Example VI

RANGE CALCULATIONS: For a given target it is possible to compute the energy for a wide range of distances from the source. Assuming a blackbody target at temperature 2500° K, the energy radiated by the target is 2.2×10^2 watts per square centimeter. Using the range portion of the calculator it is found that 7.0×10^{-5} watts per square centimeter is incident on one square centimeter of surface 1×10^3 centimeters from one square centimeter target area. At a distance of 10 nautical miles the radation received would be 2.04×10^{-11} watts per square centimeter.

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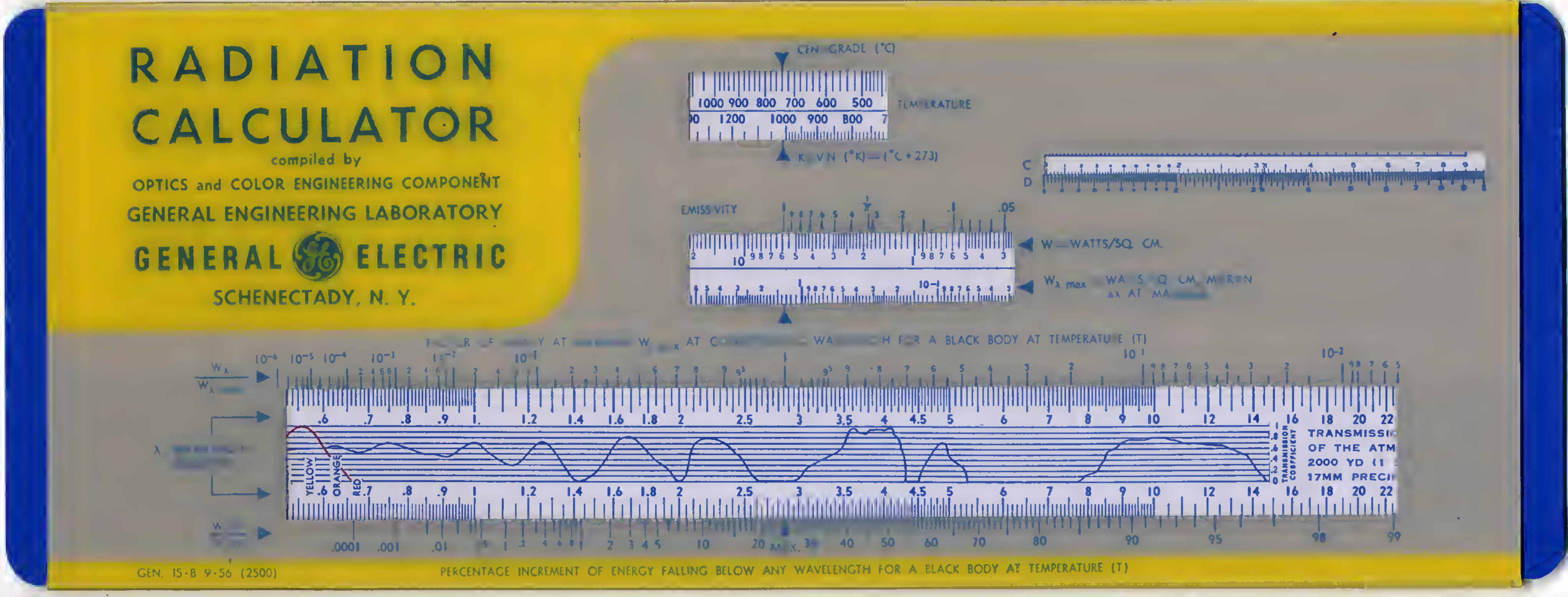
F. K. Richtmyer, E. H. Kennard, and T. Lauritsen, "Introduction to Modern Physics", McGraw-Hill Book Co.

A. N. Lowan, "Miscellaneous Physical Tables - Planck's Radiation Functions and Electronic Functions", sponsored by National Bureau of Standards.

GENERAL ELECTRIC

Schenectady, N. Y.


RADIATION
CALCULATOR
compiled by
OPTICS and COLOR ENGINEERING COMPONENT
GENERAL ENGINEERING LABORATORY
GENERAL ELECTRIC
SCHENECTADY, N. Y.
KELVIN (°K) — (°C + 273)
EMISSIVITY
W — WATTS/SQ. CM.
YELLOW
ORANGE
RED
TRANSMISSION COEFFICIENT
PERCENTAGE INCREMENT OF ENERGY FALLING BELOW ANY WAVELENGTH FOR A BLACK BODY AT TEMPERATURE (T)
GEN. 15-B 9-56 (2500)

PLANCK'S EQUATION:

$$W_\lambda = C_1\lambda^{-5}\left(e^{\frac{C_2}{\lambda T}} - 1\right)^{-1}$$

WIEN'S DISPLACEMENT LAW:

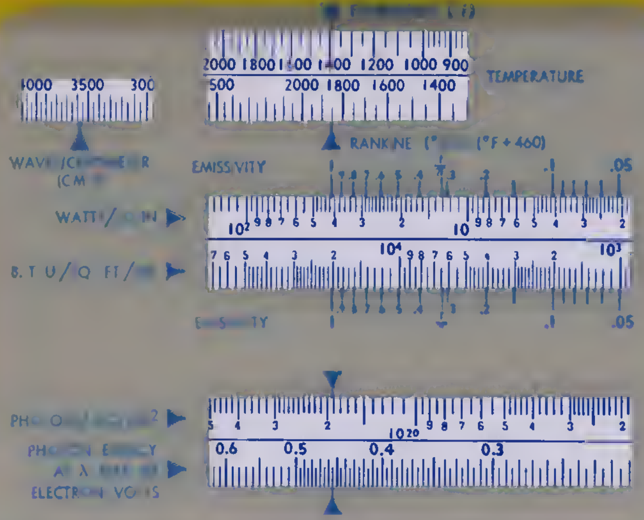
$$\lambda_m = \frac{a}{T}$$

STEFAN-BOLTZMANN LAW:

$$W = \rho\sigma T^4 \text{ or } W = \rho\sigma(T^4 - T_0^4)$$

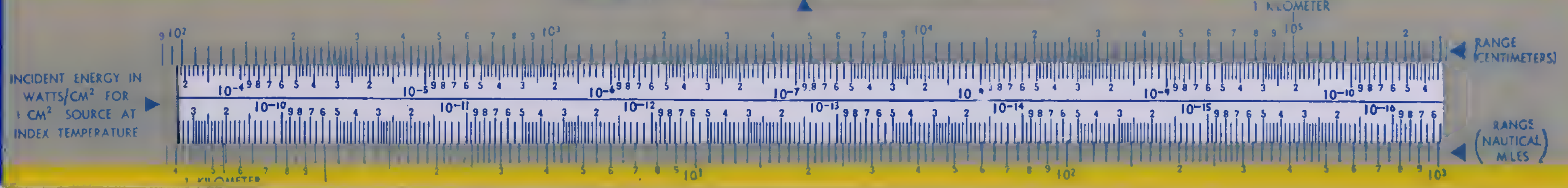
STEFAN-BOLTZMANN CONSTANT (σ)

5.6686×10^{-5} ergs cm^{-2} deg^{-4} sec^{-1}
5.6686×10^{-12} watts cm^{-2} deg^{-4}
1.354×10^{-12} cal cm^{-2} deg^{-4} sec^{-1}
3.657×10^{-11} watts in^{-2} deg^{-4}
1.797×10^{-8} Btu ft^{-2} deg^{-4} hr^{-1}
5.267×10^{-12} Kwh ft^{-2} deg^{-4} hr^{-1}
4.529×10^{-9} Kcal ft^{-2} deg^{-4} hr^{-1}



SYMBOLS AND PHYSICAL CONSTANTS

W_λ = RADIANT FLUX PER UNIT AREA PER UNIT INCREMENT OF WAVELENGTH = watts/cm²/cm Δλ or watts/cm²/micron Δλ
W = TOTAL RADIANT FLUX EMITTED PER UNIT AREA
T = ABSOLUTE TEMPERATURE OF RADIATING BODY (°K)
T_0 = ABSOLUTE TEMPERATURE OF SURROUNDINGS (°K)
λ = WAVELENGTH IN CENTIMETERS OR MICRONS
λ_m = WAVELENGTH IN MICRONS OF MAXIMA OF BLACK BODY CURVE
a = CONSTANT FOR BLACK BODY = 2897.9 MICRON DEGREES
$C_1 = 2\pi c^2 h = 3.7413\times10^{-12}$ watt cm²
C_2 = hc/k = 1.4388 cm degree
e = 2.71828 NAPERIAN BASE
ρ = EMISSIVITY FACTOR (BLACK BODY = 1)
σ = STEFAN-BOLTZMANN CONSTANT (DEG K)
c = VELOCITY OF LIGHT = 2.99793×10^{10} cm/sec = 2.99793×10^{14} micron/sec
h = PLANCK'S CONSTANT = 6.6252×10^{34} watt sec²
k = BOLTZMANN'S CONSTANT = 1.38042×10^{7} watt sec/degree
$1/\pi$ = TOTAL RADIANT FLUX PER UNIT SOLID ANGLE (CENTRAL STERADIAN)



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